Flight Surgeon Refresher Course

Section 3: Aeromedical Training

Aviation Toxicology

(FSRC308)

AVIATION TOXICOLOGY

Introduction

More than one million personnel work in the aerospace industry. This industry exposes its workforce to numerous hazards that may result in adverse health effects. Each job has its own inherent toxins that personnel may be exposed to.

As an Aircrew member you must become familiar with the toxicological hazards that are present in the aviation environment. Without being aware of these toxins you can place yourself, your soldiers, and the mission in harm's way.

The purpose of this lesson is to provide an introduction to the field of toxicology, and to minimize the exposure to toxic materials of you, your crew, and your unit.

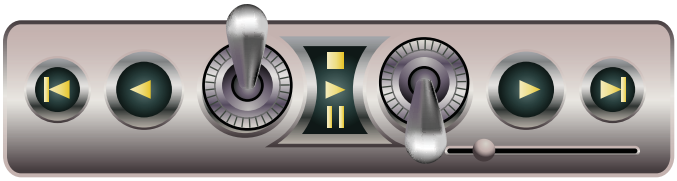
Objectives:

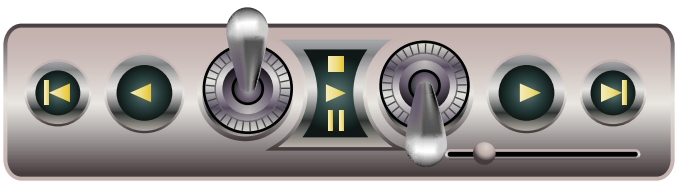
a. Define the major toxicity factors

b. Identify the major toxic hazards in the aviation environment

c. Describe the adverse health effects of major toxic hazards in the aviation environment.

d. Describe protective measures to prevent or reduce toxic substance exposure





General Terminology

It is helpful to begin by ensuring we understand some general terminology for toxicology.

Toxin.

Anything that has the potential to produce harmful effects on an organism.

Anything can be toxic in a large enough dose (e.g. oxygen, water, jelly doughnuts) but some substances are inherently more toxic.

Example: Carbon monoxide is always toxic to humans.

Antibiotics are toxic to certain bacteria, but hopefully do not act as a toxic substance to persons that are prescribed them.

Toxicology.

The scientific study of poisons, physical or chemical agents and the injury they can cause to living cells.

Exposure.

The actual contact of the harmful substance with the biological organism.

When dealing with exposures it is often useful to consider them as coming in two varieties: acute and chronic.

It is important to recognize that mere exposure does NOT guarantee a toxic response by the organism.

Acute Exposure.

A single exposure over a short period of time.

These types of exposures are often reported in the news as catastrophic events, such as accidental release of toxins into the atmosphere, resulting in numerous deaths of innocent and unwilling participants.

In aviation personnel, acute exposure may cause an unrecognized decrease in perception, abilities, and/or performance. One can see where this could cause great risk to crewmembers in flight.

Chronic Exposure.

Long-term exposure or repeated exposure over a long period of time.

It is these exposures which are often dangerous due to difficulty recognizing them and their delayed effects.

Example: cigarette smoking, which exposes the individual to the myriad toxins found in tobacco fumes. This chronic exposure often leads to the development of lung cancer and/or heart disease.

Remember, exposure does not necessarily guarantee a toxic response. Lots of smokers live long, productive lives.

Toxicity Factors.

Some of the factors that influence the toxicity of certain compounds:

Dose.

The amount of toxic agent that the body has been exposed to.

Route of Entry (Method of Exposure):

Inhalation (through the nasal-oral route into the lungs) is the most important method of getting toxins into the body.

The alveoli in the lungs are where oxygen in the air diffuses across a membrane into the blood, and contaminants in the blood, such as carbon dioxide, are excreted back into the air. If you were to stretch the alveoli out fully, they would cover an area equal to the surface area of a doubles tennis court. This large surface area allows for the adequate exchange of gases.

Inhaled toxins are rapidly absorbed into the blood stream because the membrane separating the gases in the lungs and the bloodstream is very thin, and freely permeable.

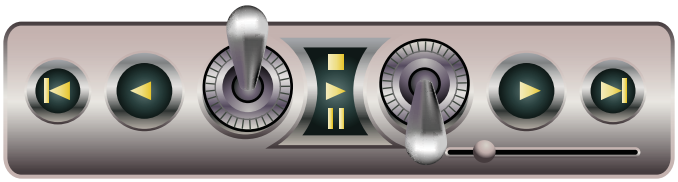
This almost instantaneous transport of toxins from the lungs to the blood (and subsequently the brain) explains the immediate effect of substances of abuse such as crack cocaine and nicotine.

Absorption through the skin. Occurs due to skin contact with the toxin.

If the flight suit is contaminated with a toxin, absorption can still occur.

The rate of absorption through the skin and any subsequent adverse effects on the body will depend, in part, on the characteristics of the toxin.

Absorption will occur through moist skin more



readily than dry.

Ingestion through the oral-gastrointestinal tract. The process that occurs when a toxin enters the gastro-intestinal tract (usually through the mouth) either intentionally or unintentionally.

Intentional ingestion would be taking an overdose of drugs or alcohol, for instance.

Unintentional ingestion can occur when aircrew members do not wash their hands before consuming food or tobacco products, especially after pre-flighting an aircraft.

Extent of Retention.

How long the toxin is kept within the body depends on the excretion rate. Some toxins have high retention rates. Lead, a heavy metal, can be ingested through the lungs or gastro-intestinal (GI) tract. It is stored in numerous body tissues, to include bone, teeth, liver, lung, kidney and brain.

DDT has an affinity for adipose tissue and beryllium has an affinity for liver, bone and kidney.

This means that these toxins can be stored for long periods of time in these tissues.

Rate of Excretion.

How quickly the body rids itself of the toxin.

Many poisons are converted to non-toxic compounds and excreted via bile or urine.

Water-soluble toxins tend to be excreted rapidly in urine, where fat-soluble toxins are stored in lipid (fat cells) and excreted more slowly.

This is why a soldier can test positive on a drug urinalysis long after discontinuing the use of illicit drugs.

Physiological Factors Affecting Toxicity		
Metabolism	**Body Fat**	**Genetics**
As you get older your metabolism slows down, so the body's ability to rid itself of toxins also slows down. Whether or not you have a concurrent illness or are taking medication also can affect the body's ability to excrete the toxin.	The amount of body fat is important if the toxin is fat-soluble. The larger the reservoir available to store fat-soluble toxins (i.e. obesity), the slower the body will excrete the toxic material. The higher the affinity of the toxin for lipid, the slower the body will excrete the toxic material.	Genetic factors (race, gender, familial traits) play an important part in determining whether or to what extent a person will react to the presence of a toxin. Example: a deficiency of alcohol dehydrogenase in many Native Americans makes it more difficult for them to metabolize alcohol.

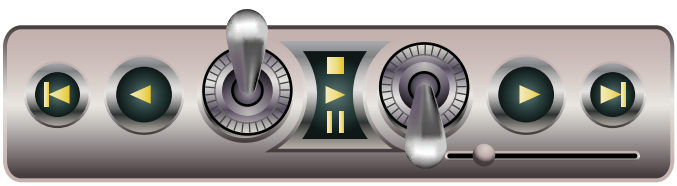
Physiochemical Factors.

Physiochemical factors relate to the biochemical processing of toxins and the end organs those toxins affect.

In other words, in involves the process in which toxins are broken down from a toxic compound to a nontoxic substance to be safely excreted from the body.

The primary organs of utilized to metabolize and excrete toxins, as discussed previously, are the kidneys and liver.

It should be intuitive that many toxic substances will have their adverse effects on these end organs.



Environmental Factors Affecting Toxicity		
Atmospheric pressure	**Temperature**	**Humidity**
Increased atmospheric pressure will increase the number of molecules of toxin per volume of air that one is exposed to. Imagine taking a low-budget dive trip down in Jamaica, and the air tanks you are using are filled with air drawn from nearby a poorly tuned generator. The carbon monoxide pumped into your tank will be breathed at depths of 3 or 4 atmospheres of pressure, increasing the risk of adverse effects while diving.	Some toxins are less problematic in winter than in summer . Warmer temperatures cause more vaporization of volatile chemicals.	Humidity (the water content in the air) may affect the concentration of gaseous toxins in inspired air.

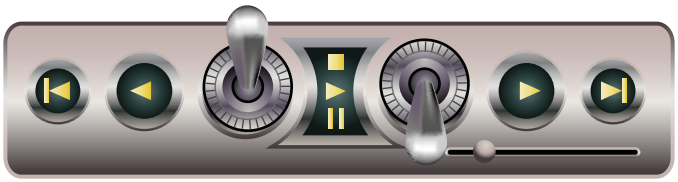
Toxic Substances in the Aviation Environment

There are a multitude of toxic materials encountered in flight and on the flightline. A basic awareness of the major hazards and their health effects is essential for the overall safety of unit personnel. The major toxins we will discuss include:

- **Aviation Fuels**
- **Combustion Byproducts (carbon monoxide, nitrogen oxides, and sulfur dioxide)**
- **Solvents**
- **Lubricants**
- **Hydraulic Fluids**
- **Fire Extinguishers**
- **Composite Materials**
- **Metals**

Aviation Fuels

- A mixture of hydrocarbons and additives.
- During the last decade, the Army changed from JP-4 to JP-8 as its primary aviation fuel.
- JP-8 is essentially kerosene with several additives.
- Examples of additives (used to prevent freezing, increase storage time, and enhance performance) are toluene, xylene, and benzene.
- These substances are known carcinogens, and can also adversely affect the liver, bone marrow, and central nervous system (CNS). The primary methods of exposure are inhalation of fumes and absorption through the skin.



Signs and symptoms of fuel exposure:

Neurological: Light-headedness, confusion, fatigue, coma, slurred speech, respiratory failure, impaired psychomotor functioning

Cardio / Respiratory: Irregular heart beats, coughing, choking, wheezing

Gastrointestinal: Nausea and vomiting

Skin: Chemical burns, blistering, and irritation due to the drying effect

Combustion By-products

Incomplete combustion of aviation fuels produces the following by-products:

Carbon monoxide:

- Is a product of incomplete combustion of petrochemicals.
- Is the most common cause of fatal poisoning in the United States.
- Is a colorless, odorless gas.
- Binds to hemoglobin with an affinity 220 times greater than that of oxygen. This is particularly problematic at altitude when oxygen is in short supply.

Signs and symptoms of carbon monoxide poisoning:

Headache	**Weakness**
Dizziness	**Nausea**
Confusion	**Loss of consciousness**

The classic (and pathognomonic) cherry red coloration of lips is not seen until CO concentration is greater than 40%.

- As little as 0.5% in the breathing atmosphere for 30 minutes will produce a blood concentration level of 45%, resulting in significant CNS disturbances.
- With as little as 10% in the blood, peripheral vision and night vision are decreased.
- It is important to note that smokers can achieve levels of CO of 7-8% just from smoking

Nitrogen dioxide:

- A deep lung irritant that can produce pulmonary edema if inhaled at high concentrations.

Solvents

- Organic bases used to dissolve other substances.
- There are both lipid soluble and water-soluble solvents.

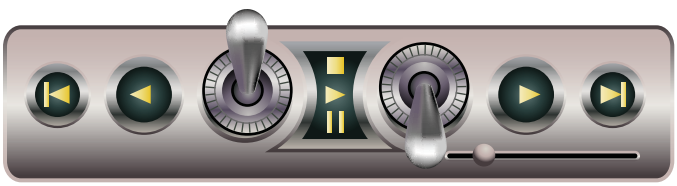
Signs and symptoms of solvent poisoning:

All solvents can produce some level of neurologic, respiratory and/or skin problems

Lipid-soluble solvents:

- Used primarily to clean residual oil from engine parts.
- This group of solvents includes Toluene.
- Toluene causes redness and blistering of the eyes, nose and respiratory tract.
- TCE (Trichloroethylene) can be identified by its sweet odor.
- Its fumes are readily absorbed from the lungs and can cause coma or death.

WARNING: Aircrew may be exposed to solvents and their effects either through Inhalation or absorption!



Water-soluble solvents:

- Are used as de-icing agents, anti-freezing agents, and cleaning agents.
- This group includes MEK (methly-ethyl-ketone), a known carcinogen that is extremely explosive.
- It can also cause central nervous system depression.

Personal Protective Measures: It is imperative to use personal protective equipment (e.g. goggles, aprons, gloves). Have adequate ventilation when using solvents. Solvents should be stored in appropriately labeled containers and segregated from other materials.

Lubricants

- Most lubricants are felt to be relatively non-toxic, although there has been an association with increased cancer risk among those chronically exposed to lubricants. Pay particular attention to mechanics' exposure.
- Improperly stored lubricants can become contaminated with bacteria, yeasts or molds.

Signs and symptoms of lubricant poisoning:

When lubricants are released under high pressure, a mist is formed, which can cause irritation to the lungs (chemical pneumonitis), and oil vapor can cause irritation of the eyes.

The lubricant itself can cause an irritant dermatitis when left in contact with the skin.

Hydraulic Fluids

- Frequently handled by mechanics and other non-rated crewmembers (to include flight medics!).
- There are several types of hydraulic fluids, which are used at high pressure to produce work in order to manipulate heavy aircraft components (e.g. rotor blades, exit ramps, turbines).
- Hydraulic fluids can be petroleum, castor oil, or silicon-based, or derived from phosphate esters.
- A popular commercial preparation is called skydrol, the military equivalent is called Milspec 5560. Each contains TCP (Tricresyl Phosphate).
- These compounds contain toxic phosphate ester-based additives.

Signs and symptoms of hydraulic fluid poisoning:

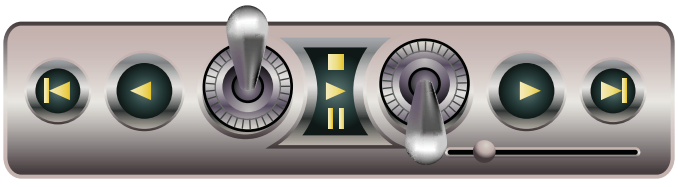
Toxicity from these hydraulic fluids can cause symptoms similar to an organophosphate (nerve agent) hit!

Cough **Runny eyes and nose**

Nausea and vomiting **Headache**

Vertigo **Impairment of judgment**

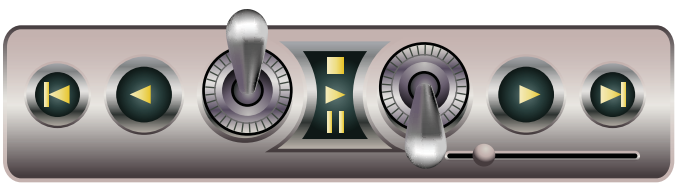
Visual Impairment



Fire Extinguishers		
Halon	**Carbon Dioxide**	**Aqueous Film Forming Foam**
• An excellent fire suppression system used in aircraft, on the flight line, and in modern armored vehicles (Bradley and M1 Tank). Often found in the engine compartment. • These types of extinguishers are also used to protect valuable electrical equipment (e.g. flight simulators) since they leave no residue to clean up. • Halon extinguishers contain a gas that interrupts the chemical reaction that takes place when fuels burn by displacing oxygen in the reaction, thereby depriving the fire of one of the three essential components it needs to exist (oxygen, fuel, source of ignition). • Halon is a central nervous system (CNS) depressant, and manufacture of halon extinguishers has been suspended in the U.S. since 1994, as it is known to deplete the ozone layer.	• The most common type of fire extinguisher. • The gas is a simple asphyxiant (which means it takes up the space oxygen usually occupies, thereby denying the fire -or people- the oxygen needed to exist). • Thus it can lead to collapse or loss of consciousness - with as little as a 10% level of carbon dioxide in ambient air.	• It is an excellent fire-fighting agent that is relatively non-toxic and helps put out the fire by separating the fuel from its oxygen source. • Skin exposure to this agent is similar to having prolonged contact with shampoo in your eyes or on your skin.

Composite Materials

- Newer aircraft are more and more commonly constructed with composite materials.
- Composites are a series of fiber layers (carbon, graphite, boron, kevlar, and fiberglass) held in an interlacing orientation with a binding resin of some type.
- Composites are being utilized due to the ability to create unique shapes (not possible with metal or plastics) and still retain strength and flexibility.
- Working, machining, sanding or rough handling of these materials may cause airborne release of particulate fibers. If inhaled, these fibers create an “asbestos-like” reaction in the lungs.
- It is imperative that repiratory protection is used when these materials are being manipulated or at a mishap scene.
- Additionally, combustion may occur (e.g. post-crash fire), releasing toxic epoxy resin fumes of hydrogen sulfide, carbon monoxide, and cyanide.



Toxic Metals

Some of the more common toxic metals found in the aviation environment:

Zinc

A common additive used in paint and plating to make it more durable and weather resistant.

Long-term inhalation exposure can lead to symptoms of “metal fume fever” (a condition which mimics upper respiratory infections) and chemical pneumonia.

Batteries

Have historically been a source of both sulfuric acid and lead.

They can also be manufactured with nickel-cadmium and lithium.

These metals are all potentially toxic

Batteries can be explosive if not handled properly.

Chromium

A common additive to paint and plating due to its corrosion resistance.

When chromium is exposed to the skin or mucous membranes it can lead to wounds known as chromium ulcers.

While usually painless, these ulcers can be chronic and require surgical excision to heal.

Beryllium

A desirable aircraft metal because it is lightweight while maintaining incredible strength. Aviation mechanical engineers appreciate its durability.

Unfortunately, a small percentage of the population (approximately 1-5% of the individuals who are exposed to beryllium dust) develops an extremely toxic reaction in the lungs.

This is an allergic cell-mediated hypersensitivity that doesn’t follow a normal dose/response curve. This means that a small dose of beryllium could possibly lead to chronic obstructive pulmonary disease in the susceptible individuals.

Beryllium can still be found in OH-58D Kiowa Warrior (mast mounted IR scope), Navy S-3 jets and other aircraft brake pads.

Cadmium

Used in batteries and electroplating and can also cause “metal fume fever.”

Cadmium is known to be extremely damaging to the kidneys, lungs, liver and bone.

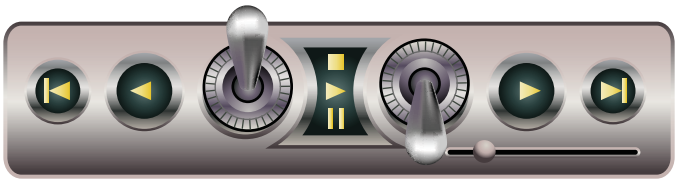
Cadmium exposure has been determined to be a risk factor in developing lung and prostate cancer.

Mag-Thorium

A combination of both Magnesium and Thorium. Due to the both their strength and light weight, they are ideal for aviation applications - from an engineer’s point of view.

This metal compound has been used in engine cowlings of the T-55 engine (seen in the CH-47 Chinooks, as well as engines in UH-1 Hueys, and OH-58 Kiowa) and other areas of high temperature.

However, Thorium is somewhat radioactive and will emit alpha-radiation. Those working around alpha emitters should take extra precautions to prevent the inhalation or ingestion of dust or grinding fragments. (Wash hands before eating/smoking!)



Protective Measures

Protective Measures to prevent or reduce toxic substance exposure:

- Personal protective measures are used to protect individuals when engineering efforts or substitution of materials or processes are impractical.
- In addition to hearing protection, these include masks, gloves, boots and aprons. The Nomex flight suit is used to protect aircrew from flash fires.
- It is imperative that aircrew make every effort to keep the Nomex from becoming contaminated with fuels and other toxic substances. If contaminated remove expeditiously.
- Avoid open flame on the flight line and place contaminated rags in the proper disposal container.
- Smoke and fumes in the cockpit are inherently dangerous, and the source of the smoke or fumes is often initially unknown.
- Good crew coordination is essential when smoke or fumes are detected, and it is important to land the aircraft as soon as possible.
- Report to the flight surgeon/aviation medical clinic any exposure to toxic substances, as pulmonary (lung) symptoms are often delayed after exposure to toxic fumes.

What else can the Flight Surgeon do?

Keep current on the hazardous materials that are located in your work area and on the flightline.

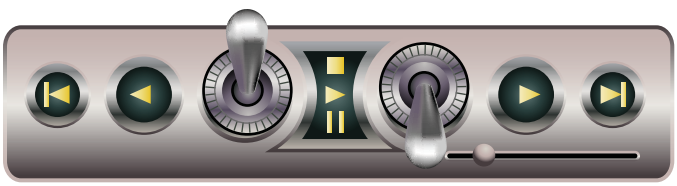
Every workplace should have a Material Safety Data Sheet (MSDS) for each toxic chemical in the workplace, and it should be conspicuously displayed for easy reference in an emergency.

The MSDS has important manufacturing information including a contact phone number, a description of the chemicals in each dangerous substance, and gives instructions for immediate first aid.

Continually provide formal and informal briefings to your crews regarding personal protective equipment and health hazards around the flightline.

Keep your head on a swivel - always be on the lookout for a wave of stupidity or carelessness.

You don't have to be the senior person around to recognize unsafe acts and make corrections!



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